OUACHITA RIVER TMDL FOR BIOCHEMICAL OXYGEN-DEMANDING SUBSTANCES AND NUTRIENTS

SUBSEGMENT 080101

SURVEYED 07/17/2001 – 07/19/2001

TMDL REPORT

Engineering Group 2
Environmental Technology Division
Office of Environmental Assessment
Louisiana Department of Environmental Quality

JULY 31, 2002

EXECUTIVE SUMMARY

This report presents the results of a calibrated modeling analysis of the Ouachita River from Sterlington to the Columbia Lock and Dam near Riverton. The modeling was conducted to establish a TMDL for biochemical oxygen-demanding pollutants for the Ouachita River watershed. The river is listed on the 2000 305(b) list as not supporting fish and wildlife propagation due to organic enrichment/low DO, requiring the development of a total maximum daily load (TMDL) for dissolved oxygen. It is also listed on the court-ordered 303(d) list as impaired due to nutrients. This TMDL establishes load limitations for oxygen-demanding substances and goals for reduction of those pollutants. LDEQ's position, as supported by the ruling in the lawsuit regarding water quality criteria for nutrients (Sierra Club v. Givens, 710 So.2d 249 (La. App. 1st Cir. 1997), writ denied, 705 So.2d 1106 (La. 1998), is that when oxygen-demanding substances are controlled and limited in order to ensure that the dissolved oxygen criterion is supported, nutrients are also controlled and limited. The implementation of this TMDL through wastewater discharge permits and implementation of best management practices to control and reduce runoff of soil and oxygen-demanding pollutants from nonpoint sources in the watershed will also control and reduce the nutrient loading from those sources.

Maps showing the portion of the river that was modeled and the location of dischargers may be found in Appendix A. Bayou Bartholomew is the most significant tributary. The modeled portion of the river comprises the lower 83 miles of Subsegment 080101, which is 102 miles in length.

The Ouachita River originates in the Ouachita Mountains of Arkansas near the Oklahoma border and flows approximately 605 miles to the confluence with the Tensas River near Trinity, Louisiana, where the two rivers form the Black River. The Black River flows an additional 42 miles to the Red River. There are dams on the river at ORM 25 near Jonesville, at ORM 117 near Riverton, at ORM 227 near Felsenthal, Arkansas, and at ORM 288 in Arkansas.

The water quality criteria for dissolved oxygen for Segment 080101 of the Ouachita River are 3.0 mg/l for June and July, 4.5 mg/l for August, and 5.0 mg/l for September through May.

Major dischargers, existing or planned, in the modeled reach, are Ouachita Power (not yet operating), Entergy Sterlington, the Town of Sterlington POTW, Koch Nitrogen, Angus Chemical, Entergy Monroe, West Monroe POTW, Riverwood International, and the City of Monroe POTW. The West Monroe facility and Riverwood discharge to Judy Slough, the discharge from which to the Ouachita River is controlled by Riverwood at their Outfall 001.

The model used was Qual2E using a windows interface written at Tetra Tech and General Science Corporation. The history of Qual2E begins with Qual-I, developed by F.D. Masch and Associates and the Texas Water Development Board, 1970-71. The version used was developed under a cooperative agreement between Tufts University, Department of Civil Engineering, and the EPA Center for Water Quality Modeling. This version of Qual2E is available from the U.S. Environmental Protection Agency.

The model has been calibrated to data from a survey conducted by the Louisiana Department of Environmental Quality on July 17-19, 2001. Projections have been made for the months of May through September and November. The most critical conditions were encountered in August for the summer months and November for the winter months. The projections for these two months were used to calculate the summer and winter season TMDLs. The projections indicate that the river is dominated by nonpoint but that point source impacts are significant. The minimum dissolved oxygen occurs in a portion of the river just upstream of the dam at Riverton, where the river velocities are lowest. In order to meet the August DO criteria of 4.5 mg/l it was necessary to reduce headwater loading by 15 percent, and nonpoint loading by 30 percent. It was also necessary to reduce the loading from Riverwood Outfall 001, Judy Slough, by 15 percent. Other point source discharges can remain at their current permit limits. No reductions were required for the winter season. The summer and winter allocations and TMDLs are as follows:

Table 1 - Summer Allocations and TMDLs

PARAMETER	WLA (lbs/day)	LA (lbs/day)	MOS (lbs/day)	TMDL (lbs/day)
UCBOD	21,406	101,947	16,679	140,032
ORG-N	7,334	21,990	4,277	33,601
NH_3-N	3,125	666	855	4,646
SOD	0	5.0	0.6	5.6
TOTAL	31,865	124,608	21,812	178,285

Table 2 - Winter Allocations and TMDLs

PARAMETER	WLA (lbs/day)	LA (lbs/day)	MOS (lbs/day)	TMDL (lbs/day)
UCBOD	28,841	139,057	22,661	190,558
ORG-N	8,505	27,779	5,213	41,497
NH_3-N	3,714	765	1,014	5,493
SOD	0	5.0	0.6	5.6
TOTAL	41,060	167,606	28,888	237,554

The winter TMDL does not represent the total assimilative capacity of this portion of the Ouachita River. Excess winter capacity over that allocated to point and nonpoint sources and margin of safety, does exist as evidenced by the difference between the projected and criteria dissolved oxygen. The amount of this excess varies with river mile and is held in reserve.

Additional model runs were conducted to evaluate the impact of nutrients on Ouachita River dissolved oxygen at August critical conditions, as discussed in Section 7. These model runs did not indicate that the dissolved oxygen is significantly impacted by increased nutrient discharges or by increased nutrient levels in the Ouachita River. This work does not, therefore, suggest that a TMDL for nutrients is needed.

LDEQ will work with other agencies such as local Soil Conservation Districts to implement agricultural best management practices in the watershed through the 319 programs. Louisiana's Nonpoint Source Pollution Management Plan outlines Louisiana's approach to nonpoint source pollution control. It describes the types of projects that have been and will be implemented, and it presents information on BMPs that have been determined to be technically feasible and effective in reduction of pollutant loadings and runoff. LDEQ will also continue to monitor the waters to determine whether standards are being attained.

In accordance with Section 106 of the federal Clean Water Act and under the authority of the Louisiana Environmental Quality Act, the LDEQ has established a comprehensive program for monitoring the quality of the state's surface waters. The LDEQ Surveillance Section collects surface water samples at various locations, utilizing appropriate sampling methods and procedures for ensuring the quality of the data collected. The objectives of the surface water monitoring program are to determine the quality of the state's surface waters, to develop a long-term database for water quality trend analysis, and to monitor the effectiveness of pollution controls. The data obtained through the surface water monitoring program is used to develop the state's biennial 305(b) report (*Water Quality Inventory*) and the 303(d) list of impaired waters. This information is also utilized in establishing priorities for the LDEQ nonpoint source program.

The LDEQ has implemented a watershed approach to surface water quality monitoring. Through this approach, the entire state is sampled over a five-year cycle with two targeted basins sampled each year. Long-term trend monitoring sites at various locations on the larger rivers and Lake Pontchartrain are sampled throughout the five-year cycle. Sampling is conducted on a monthly basis or more frequently if necessary to yield at least 12 samples per site each year. Sampling sites are located where they are considered to be representative of the waterbody. Under the current monitoring schedule, targeted basins follow the TMDL priorities. In this manner, the first TMDLs will have been implemented by the time the first priority basins will be monitored again in the second five-year cycle. This will allow the LDEQ to determine whether there has been any improvement in water quality following implementation of the TMDLs. As the monitoring results are evaluated at the end of each year, waterbodies may be added to or removed from the 303(d) list.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. Introduction

This report presents the results of a calibrated modeling analysis of the Ouachita River from Sterlington to the Columbia Lock and Dam near Riverton. The modeling was conducted to establish a TMDL for biochemical oxygen-demanding pollutants for the Ouachita River watershed. The river is listed on the 2000 305(b) list as not supporting fish and wildlife propagation due to organic enrichment/low DO, requiring the development of a total maximum daily load (TMDL) for dissolved oxygen. It is also listed on the court-ordered 303(d) list as impaired due to nutrients. This TMDL establishes load limitations for oxygen-demanding substances and goals for reduction of those pollutants. LDEQ's position, as supported by the ruling in the lawsuit regarding water quality criteria for nutrients (Sierra Club v. Givens, 710 So.2d 249 (La. App. 1st Cir. 1997), writ denied, 705 So.2d 1106 (La. 1998), is that when oxygen-demanding substances are controlled and limited in order to ensure that the dissolved oxygen criterion is supported, nutrients are also controlled and limited. The implementation of this TMDL through wastewater discharge permits and implementation of best management practices to control and reduce runoff of soil and oxygen-demanding pollutants from nonpoint sources in the watershed will also control and reduce the nutrient loading from those sources.

Maps showing the portion of the river that was modeled and the location of dischargers may be found in Appendix A. Bayou Bartholomew is the most significant tributary. The modeled portion of the river comprises the lower 83 miles of Subsegment 080101, which is 102 miles in length.

The water quality criteria for dissolved oxygen for Segment 080101 of the Ouachita River are 3.0 mg/l for June and July, 4.5 mg/l for August, and 5.0 mg/l for September through May.

Major dischargers, existing or planned, in the modeled reach, are Ouachita Power (not yet operating), Entergy Sterlington, the Town of Sterlington POTW, Koch Nitrogen, Angus Chemical, Entergy Monroe, West Monroe POTW, Riverwood International, and the City of Monroe POTW. The West Monroe facility and Riverwood discharge to Judy Slough, the discharge from which to the Ouachita River is controlled by Riverwood at their Outfall 001.

2. Study Area Description

2.1 Ouachita Basin and Ouachita River, Subsegment 080101

The Ouachita River's source is found in the Ouachita Mountains of west central Arkansas near the Oklahoma border. The Ouachita River flows approximately 605 miles through northeastern Louisiana to the confluence with the Tensas River near Trinity, Louisiana, where the two rivers form the Black River. The Black River flows an additional 42 miles to the Red River. There are dams on the river at ORM 25 near Jonesville, at ORM 117 near Riverton, at ORM 227 near Felsenthal, Arkansas, and at ORM 288 in Arkansas. The Ouachita Basin covers over 10,000 square miles of drainage area. Most of the basin consists of rich, alluvial plains cultivated in cotton and soybeans. The northwest corner of the basin is forested in pine, which is commercially harvested (LA DEQ, 1996). Elevation and merged infrared/spot images of the basin can be found in Appendix A.

Subsegment 080101 is the Ouachita River from the Louisiana-Arkansas state line to the Columbia Lock and Dam at Riverton. The river is designated a scenic water from the state line to confluence with Bayou Bartholomew just above Sterlington, a distance of approximately 19 river miles. The GAP land cover mapping in Appendix A gives an indication of the land use in the subsegment.

Table 3 - Land use in Subsegment 080101

Land use	Area (m^2)	Percent
Wetland	284,258,700	20.7
Upland Forest	584,829,900	42.6
Upland Scrub	205,994,700	15.0
Agriculture/Grassland	203,208,300	14.8
Urban	14,597,100	1.1
Water	80,486,100	5.9

2.2 Water Quality Standards, Uses, and Support Issues

Water quality criteria and designated uses are specified in Table 4.

Table 4 - Water Quality Numerical Criteria and Designated Uses

Parameter/Use	Criteria/Degree of support			
	June	July	August	September-May
Chlorides (mg/l)	160	160	160	160
Sulfates (mg/l)	35	35	35	35
Dissolved oxygen (mg/l)*	3.0	3.0	4.5	5.0
PH	6.0-8.5	6.0-8.5	6.0-8.5	6.0-8.5
Temperature (^oC)	33	33	33	33
TDS (mg/l)	350	350	350	350
Drinking water	Fully supporting			
Primary contact recreation	Fully supporting			
Secondary contact recreation	Fully supporting			
Fish and wildlife propagation	Not supporting due to Organic enrichment/low DO. Other suspected causes of impairment are cadmium, Copper, lead, mercury, and metals.			

* These seasonal criteria may be unattainable during or following naturally occurring high flow (when the gauge at the Felsenthal Dam exceeds 65 feet ad also for the two weeks following the recession of flood waters below 65 feet), which may occur from May through August. Naturally occurring conditions that fail to meet criteria should not be interpreted as violations of the criteria. (LADEQ Environmental Regulatory Code, 2000)

The river is listed on the 2000 305(b) list as not supporting fish and wildlife propagation due to organic enrichment/low DO, requiring the development of a total maximum daily load (TMDL) for dissolved oxygen.

Historic data may be found in Appendix N. Data for August were plotted for the years 1970 to present, where available. Dissolved oxygen is showing a trend upward at Sterlington since 1990, but the DO at Monroe and Columbia does not show a trend. TOC is trending upward at Columbia, while TKN is trending slightly downward. Monitoring data for the Columbia Lock and Dam are available for 1999 only. Dissolved oxygen data at the dam show criteria violations in May, August, and September.

2.3 Wastewater Discharges

The following are the significant dischargers to the modeled portion of the Ouachita River.

Table 5 – Major Discharger Inventory for Subsegment 080101

					Permit limits		
Facility	Outfall no.	Permit no.	Outfall ORM	Design flow (mgd)	Temp (^oF)	$CBOD_5$	NH_3-N
Ouachita Power	001&002	LA0112780	192.90	1.24	99		
Entergy Sterlington	001&002	LA0007579	192.46	159	112		
Town of Sterlington POTW	001	LA0046809	191.81	0.15	30	30 mg/l	
Koch Nitrogen	001	LA0094846	191.36	2.49			342 lb/d
Angus Chemical	002	LA0007854	189.24	0.75		288 lb/d	
Entergy Monroe	001&002	LA0007765	169.29	116	106		
Riverwood International	001	LA0007617	160.91	22.6		5.95Q**-240 lb/d	
West Monroe POTW	*	LA0043982		6.87			
City of Monroe POTW	001	LA0038741	159.56	12.0		10 mg/l	2 mg/l

* Effluent combined with Riverwood Outfall 401 and permitted as Riverwood Outfall 001.
** Q = the 7 day running average of the Ouachita River flow at the state line in cfs.

2.4 Prior Studies

Several studies of the Ouachita River between the Felsenthal Dam in Arkansas and Sterlington, Louisiana have been conducted; HydroQual of Mahwah, NJ, 1992 and AquAeTer of Brentwood, TN, 1999. This reach of the river includes the upper 19 miles of Subsegment 080101. Both studies were done to assess the impact of the Georgia Pacific Paper Mill at Crossett, Arkansas. That study found that the limitations for GP proposed by the Arkansas DEQ would not cause a violation of Ouachita River water quality criteria in Arkansas or Louisiana, but would leave very little additional assimilative capacity in the river between the state line and Sterlington, Louisiana.

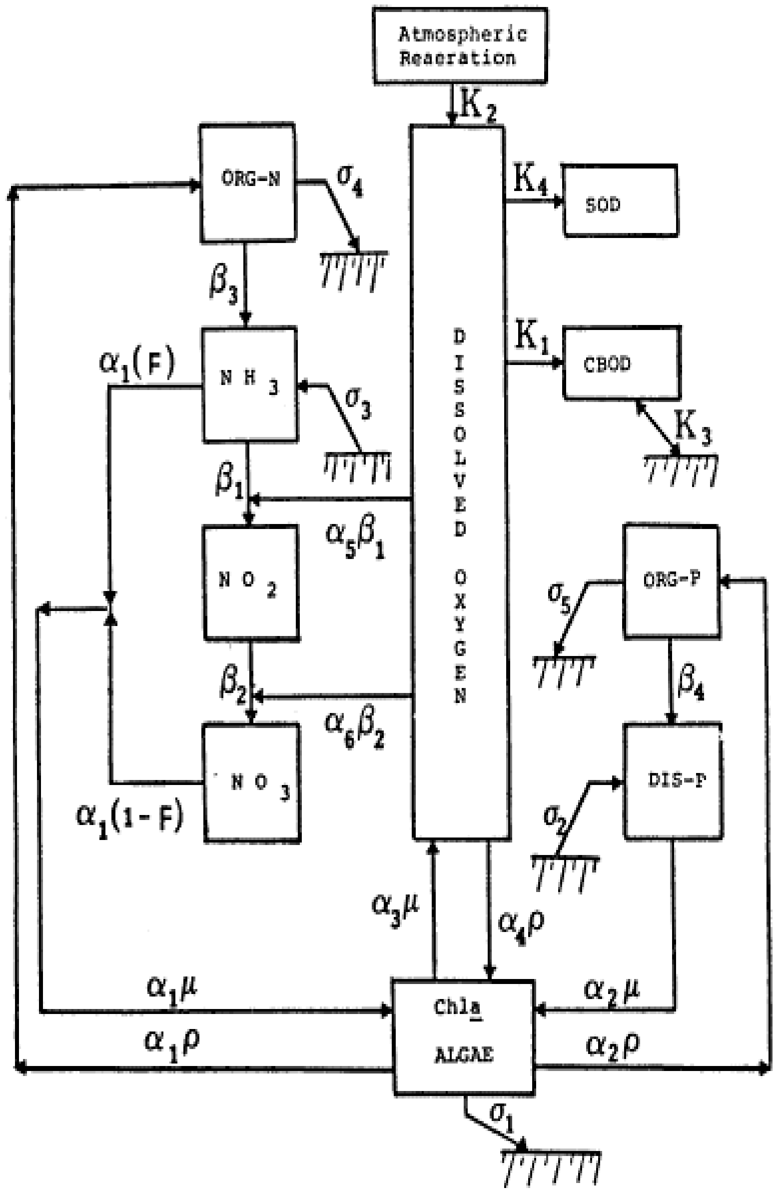
3. Model Calibration

3.1 Program Description

The model used was Qual2E using a windows interface written at Tetra Tech and General Science Corporation. The history of Qual2E begins with Qual-I, developed by F.D. Masch and Associates and the Texas Water Development Board, 1970-71. The version used was developed under a cooperative agreement between Tufts University, Department of Civil Engineering, and the EPA Center for Water Quality Modeling. This version of Qual2E is available from the U.S. Environmental Protection Agency.

Qual2E is capable of modeling the interactions between nutrients, algae, and carbonaceous and nitrogenous oxygen demand, as shown in Figure 1.

Figure 1 - Major Constituent Interactions in Qual2E



3.2 Overview

The model has been calibrated to data from a survey conducted by the Louisiana Department of Environmental Quality on July 17-19, 2001. Facility information, including current permit limitations, was obtained from LDEQ permit files. Ouachita River flow records were obtained from the U.S. Geological Survey. A HEC-2 hydrologic model of the Ouachita River was obtained from the U.S. Army Corps of Engineers. Weather data was obtained from the Louisiana Office of State Climatology.

This model of the Ouachita River from Sterlington to the Columbia Dam made use of the ability of Qual2E to model the interactions shown in Figure 1 so that the impact of nutrient on dissolved oxygen levels in the river was accounted for. Water temperature was also modeled so that the impact of several power plants using once-through, non-contact, cooling water could be assessed.

3.3 Survey Data, Appendix B and Appendix O

The data collected during the July 17-19, 2001 survey may be found in Appendix O, along with climate data from the Louisiana Office of State Climatology (LOSC) and Ouachita River flow data from the U.S. Geological Survey (USGS). A summary of that data is presented in Appendix B.

Plots of the continuous monitoring data, dissolved oxygen, pH, conductivity, and temperature, are presented. Continuous monitors were deployed at seven locations in the Ouachita River. Evidence of algal activity was found at all sites; however, that activity appears to be intermittent, with production in evidence on some days but not others. The variation in pH tracks the dissolved oxygen very closely, confirming the presence of algal activity. At most sites, the in-situ measurements of dissolved oxygen are close to the continuous monitor data.

In-situ runs were made above and below the Entergy power plants, both of which were in operation, to look for changes in dissolved oxygen and temperature. The measurement at the power plant was, in each case, taken as close to the discharge plume as possible. The results are presented as plots in Appendix B. The power plants are discharging at a slightly lower dissolved oxygen than their intake by an average of about 0.2 mg/l. The discharge temperature used in the calibration was obtained from Entergy.

All water quality analysis work was done by the LDEQ Water Laboratory. Sixty day BOD time series plots and the calculation of ultimate BOD and decay rates are included in Appendix B along with laboratory analytical results. Discharge flow data and water quality samples were obtained from those facilities discharging to the Ouachita.

Also in Appendix B are a summary of survey hydrologic data, USGS flow data from the state line slope gauge, in-situ profile data, and climate data (wet and dry bulb temperature, barometric pressure, and wind velocity) for July 18 from the LOSC. The in-situ profile data indicate no change in temperature and very little change in dissolved oxygen from top to bottom in the Ouachita River, an indication of fairly good mixing and/or negligible sediment oxygen demand. Ouachita River flows were obtained using an acoustic-doppler flow meter.

3.4 Hydrology, Appendix P and E

A HEC-2 model developed by the U.S. Army Corps of Engineers (USCOE) in 1979-80 was used as a basis for the hydrology. This model covers the Ouachita and Black Rivers from their junction with the Red River to river mile 338.4 at Camden, Arkansas. The input and output files may be found in Appendix P. The model output data was used to develop the hydrologic (Leopold) equations that are used by Qual2E to describe the river geometry (depth and velocity) as a function of flow. An example of the data work-up for Reach 1 may be found following the output file. A similar data file for each reach was developed but not included in the report. Following the data file may be found plots of the calculated average depth and velocity for each reach. Curve fits yield the hydrologic coefficients for Qual2E. These coefficients were used as a starting point for the hydrologic calibration of the model.

The model was first calibrated to the flows and depths measured during the survey, then to the velocity calculated from measured width, depth and flow. Calibration to depth and velocity was achieved by varying the hydrologic coefficients calculated from the HEC-2 model. The calibration depths and velocities are marked on the plots.

The flow, depth, and velocity calibration plots may be found in Appendix E. In the flow calibration plot, flow data from the U.S. Geological Survey (Arkansas) state line slope gauge is projected downstream, without dispersion, in accordance with the time of travel, and superimposed on the flow calibration plot. The USGS plot is thus an estimate of what the flow in each reach would have been on July 18 without any flow averaging by dispersion. The LDEQ measured flow is quite close to being an average of the projected USGS data, indicating that both USGS and LDEQ measurements are probably reliable.

The increase in measured flow below Bayou Bartholomew is probably mostly due to variation in headwater flow from the USCOE operated Felsenthal Dam. This was simulated in the model by adding incremental flow to each reach at the water quality concentrations measured in that reach. However, since Qual2E does not have the ability to input nonpoint load for calibration, incremental input was also used to input CBOD, organic nitrogen, and organic phosphorus to achieve calibration. The source of the additional CBOD, Org-N, and Org-P loading is unknown. It could be benthic but is more likely to be accumulated loading from small tributaries which had no measurable flow.

3.5 Other Calibration Input, Appendix C

Appendix C contains a summary of the point source (including tributary) calibration input data plus the point source model element calculations and reaeration calculations. Reaeration was calculated as the greater of the O'Connor-Dobbins equation or a minimum K_L of 2.3 (Louisiana Total Maximum Daily Load Technical Procedures, LADEQ), modified by the Mattingly relation (Rates, Constants, and Kinetic Formulations in Surface Water Quality Modeling, USEPA) for wind-aided aeration. For the most part, velocities in the Ouachita River are below the range of the O'Connor-Dobbins equation, and wind plays a significant role in the aeration of the Ouachita.

3.6 Rates and Constants

The global rates and constants of Qual2E input sections 1 and 1A are set within the range allowed by Qual2E as documented in the Qual2E Windows Interface Users Guide, at a median or average value from the EPA Rates and Constants Manual, taking into account the default value listed by the Windows Users Guide. Other comments concerning these constants may be found in 3.6.1 and 3.6.2. Input sections 6, 6A, and 6B contain reach specific rates, and some comments on these may be found in 3.6.3.

3.6.1 Program Control Constants

The time step is used only for a dynamic simulation. One hour seems to be the best choice for model convergence. The maximum route time is either the run time of a dynamic simulation or the maximum number of iterations allowed for a steady state simulation. The standard meridian was set to 90 degrees for the Central Time Zone. The evaporation coefficient AE controls the evaporation rate when modeling temperature; BE controls evaporation related to wind speed. AE and BE were varied to calibrate temperature. The basin elevation was set just over the control elevation of 52 feet for the Columbia Dam. The value of dust attenuation was set near the maximum of the Qual2E range, consistent with low elevation.

3.6.2 Global Algal, Nutrient, and Light Constants

Oxygen uptake by ammonia and nitrite oxidation was set at the stoichiometric values. The algae growth and respiration rates were set within the allowable range to calibrate chlorophyll a. Light averaging option 3 is the default for dynamic simulation if temperature is simulated, and was therefore selected for both dynamic and steady state runs. The number of daylight hours and the total daily solar radiation are needed only for light averaging options 2 or 4. Otherwise this information is calculated by the program. A nitrification inhibition coefficient (KNITRF) of 0.6 was selected to approximate QUALTX and LAQUAL inhibition option 1, as shown by the values of "CORDO" in Table 6.

Table 6 - Nitrification Inhibition Options

NITRIFICATION INHIBITION OPTIONS VALUES OF CORDO				
DO (mg/l)	LAQUAL OPTION 1 "CORDO"	LAQUAL OPTION 2 "CORDO"	ENTER "KNITRF"	QUAL2E "CORDO"
10.0	1.000	1.00000000	0.6	0.998
9.0	1.000	1.00000000	0.6	0.995
8.0	1.000	1.00000000	0.6	0.992
7.0	0.981	0.98130841	0.6	0.985
6.0	0.952	0.95238095	0.6	0.973
5.0	0.915	0.91463415	0.6	0.950
4.0	0.863	0.86330935	0.6	0.909
3.0	0.789	0.78947368	0.6	0.835
2.0	0.674	0.67415730	0.6	0.699
1.0	0.469	0.05000000	0.6	0.451
0.5	0.291	0.00356489	0.6	0.259
0.2	0.136	0.00010862	0.6	0.113
0.1	0.072	0.00000774	0.6	0.058
0.0	0.000	0.00000000	0.6	0.000

KNITRF = First order nitrification inhibition coefficient
CORDO = Fraction of maximum nitrification rate

3.6.3 Reach Specific Constants

The rate constants for CBOD, Org-N, NH3-N, NO_2-N, and Org-P decay were determined by calibration. The calculation of reaeration rates is discussed in 3.4. Settling rates were set at relatively low default values. The chlorophyll a to algae ratio is consistent with information in the

Rates and Constants manual. The non-algal light extinction coefficient was calculated from a relation with Secchi disk depth that may be found in Thomann and Mueller.

3.7 Calibration Dynamic Plots, Appendix D

The calibration was run in quasi-dynamic mode and the results for dissolved oxygen, temperature, and chlorophyll-a were plotted against time for the top and bottom elements of the model and for several elements in between using a program written by LDEQ. Qual2E is initially trying to reach equilibrium, after which it displays the diurnal variation of these parameters. Comparing this projected variation with the variation measured by the continuous monitors, it is clear that the model greatly understates the variation of dissolved oxygen and slightly understates the variation of temperature. The temperature variation at the 1 meter measurement depth is probably greater than the variation of the average water column temperature. Likewise, the variation of dissolved oxygen at the 1 meter measurement depth is probably greater than the variation of the average water column DO. This may explain the model understating the temperature cycle but it seems unlikely that it explains the gross understatement of the dissolved oxygen cycle. Chlorophyll-a was sampled during the day WQ runs and we therefore have only daytime maximum values for this parameter.

The dynamic run was made in such a way that the last element should coincide with the July 18 calibration, and the diurnal variation should therefore bracket the steady state runs. This behavior was observed for dissolved oxygen and chlorophyll-a but not for temperature. Because of the suspect nature of the dynamic runs, all calibration and projection was carried out in steady state mode.

3.8 Steady State Calibration Plots, Appendix E

The simulated parameters, dissolved oxygen, UCBOD, organic-nitrogen, ammonia-nitrogen, nitrates plus nitrites, organic phosphate, dissolved phosphate, and chlorophyll-a were calibrated to measured data. The model was calibrated to the average temperature and DO measured at the one meter depth since LDEQ water quality assessment is carried out at that depth.

Calibration to the measured DO required that benthic loading be dropped to nearly zero (a small amount of SOD was used to fine tune the calibration) and that CBOD and organic-nitrogen decay rates significantly lower than bottle rates be used. Since dissolved oxygen does not vary greatly over the water column, the fact that dissolved oxygen was measured at the one meter depth instead of mid-depth was not a factor, and the decay rates obtained by calibration are probably correct.

Point source dischargers were represented in the calibration at the concentrations and flows obtained by the 2001 survey. The Entergy power plant discharge concentrations are assumed equal to Ouachita River concentrations at the point of intake except for dissolved oxygen, for which a drop of 0.2 mg/l was used as discussed in Section 3.3, and temperature, which was obtained from Entergy. The Entergy Monroe power plant was in operation during the survey. The Ouachita Power generating facility has not yet come on line.

The Sterlington POTW was not discharging at the time of the 2001 survey.

For those dischargers for whom temperature and dissolved oxygen could not be measured, defaults of 86 ^{o}F and 2 mg/l were assumed. Survey data for temperature and DO were obtained for the Riverwood outfall 001.

As mentioned previously, climate data consisting of wet and dry bulb temperature, barometric pressure, and wind velocity were obtained from the Louisiana Office of State Climatology.

4. Model Projections

4.1 Critical Conditions, Seasonality and Margin of Safety

The Clean Water Act requires the consideration of seasonal variation of conditions affecting the constituent of concern, and the inclusion of a margin of safety (MOS) in the development of a TMDL.

Graphical and regression analysis techniques have been used by LDEQ historically to evaluate the temperature and dissolved oxygen data from the Ambient Monitoring Network and run-off determinations from the Louisiana Office of Climatology water budget. Since nonpoint loading is conveyed by run-off, this was a reasonable correlation to use. Temperature is strongly inversely proportional to dissolved oxygen and moderately inversely proportional to run-off. Dissolved oxygen and run-off are also moderately directly proportional. The analysis concluded that the critical conditions for stream dissolved oxygen concentrations were those of negligible nonpoint run-off and low stream flow combined with high stream temperature.

When the rainfall run-off (and non-point loading) and stream flow are high, turbulence is higher due to the higher flow and the temperature is lowered by the run-off. In addition, run-off coefficients are higher in cooler weather due to reduced evaporation and evapotranspiration, so that the high flow periods of the year tend to be the cooler periods. Reaeration rates and DO saturation are, of course, much higher when water temperatures are cooler, and BOD decay rates are much lower. For these reasons, periods of high loading are periods of higher reaeration and dissolved oxygen but not necessarily periods of high BOD decay.

In the case of the Ouachita River, the above conditions are sometimes overwhelmed by the conveyance of highly loaded floodwaters from swamps upstream. This condition is exempted from the criteria and is not considered by this model. With the exception of these flood conditions, critical conditions in the Ouachita are probably periods of low flow and/or high water temperature. With this in mind, the months of May through September were chosen for summer season projections. The lowest 7Q10 flow and the highest 90 percentile temperature for the Ouachita both occur in August.

The lack of a natural background river similar to the Ouachita leaves us with no basis for estimating natural background loading. Model loading will therefore be considered on an overall basis, man-made plus natural background. Because of this, an explicit MOS of 10% was used for all nonpoint loads, while 20% was used for the man-made point source loads to account for future growth, safety, model uncertainty, and data inadequacies.

4.2 Overview and Comments on the Projections

The model was successfully calibrated and was projected at monthly critical temperature and flow conditions for May through September to represent the summer season and for November to represent the winter season. The lowest summer season TMDL was obtained for the month of August and this TMDL and allocations will thus be the summer season TMDL. The most stringent temperature and flow conditions for the winter season occur in November. The summer season is considered to be the months of May through October and the winter season November through April as per the Louisiana Total Maximum Daily Load Technical Procedures.

Ouachita River water quality data from the 2001 survey for survey Site OR1 above the junction with Bayou Bartholomew was used as a starting point for the projections. Survey data was also used as a starting point for tributary inputs.

Incremental flow was assumed to be negligible for the projections. A very small incremental flow was used solely to convey nonpoint loading of CBOD, Org-N, and Org-P. As a starting point, the concentrations were increased to give a loading rate equal to calibration loading plus a margin of safety. NH_3-N, NO_x, dissolved-P, and Chl-a concentrations were set to zero. It was assumed that nonpoint BOD and nutrient loading would predominately be in the form of CBOD and organic nitrogen and phosphorus compounds.

Point source dischargers were represented in the projections in accordance with their permit limitations. Non-permitted parameters were input at the levels measured in the survey of 2001. The Entergy power plant discharge concentrations are assumed equal to Ouachita River concentrations at the point of intake except for temperature, which is set in accordance with the permit, and dissolved oxygen, for which an 0.2 mg/l drop from intake concentration was assumed. The Ouachita Power generating plant is represented in the projections in accordance with their permit.

The Sterlington POTW was not discharging at the time of the 2001 survey. Non-permitted parameters typical of oxidation pond samples taken during the 1994 Chauvin Bayou survey were used.

For those dischargers for whom temperature and dissolved oxygen could not be measured, defaults of 86 ^{o}F and 2 mg/l were assumed. The Riverwood outfall 001 was modeled at the dissolved oxygen measured during the survey and the projection temperature was assumed the same as Cheniere Creek.

Monthly average wet and dry bulb temperature and wind velocity were worked up from raw data supplied by the Louisiana Office of State Climatology.

A series of runs was made to assist in judging the impact on the Ouachita River minimum dissolved oxygen of the various point and nonpoint loads. The August run without load reduction was used as a basis and each load was evaluated in comparison to that basis. The minimum DO was determined to be just above the dam at Riverton, where the river velocity is lowest. The loads are listed below in descending order of impact, and the impact in terms of the decrease in minimum dissolved oxygen concentration is noted.

Nonpoint (incremental + benthic) loading ……………...…………………..	1.68 mg/l
Riverwood International ……………………………...…………...…....	0.41 mg/l
Headwater loading ………………………...………..…………………	0.20 mg/l
Monroe POTW …………………………………………..………..…..	0.12 mg/l
Entergy Monroe ……………………………………………………...	0.10 mg/l
Tributary loading ……………………………………..…………….	0.03 mg/l
All other dischargers ………………………………….……………	0.00 mg/l

The greatest impact is from headwater, nonpoint, and the Riverwood discharge. Reductions of 15 % in headwater loading, 30% in non-point loading, and 15% in loading from Riverwood allowed the August criteria to be met. The Monroe POTW has limitations of 10mg/l CBOD5 and 2 mg/l NH_3-N and was not reduced further. The impact of the Entergy Monroe generating plant is due to the discharge temperature limitation.

4.3 Projection Input Summary, Appendix G

4.3.1 The “Model Criteria and Critical Conditions” sheet presents the dissolved oxygen criteria for the Ouachita River, and monthly critical conditions for temperature, flow, and dissolved oxygen for the Ouachita, Bayou Bartholomew, Bayou deLoutre, Bayou d’Arbonne, Cheniere Creek, and Chauvin Bayou. The source of the data is also given. The Julian “day of year start time” for the model is listed for each month.

The monthly 7Q10 flows for the Ouachita River at the Arkansas-Louisiana state line are taken from Appendix F of the 1992 HydroQual modeling report, for which the reference is an Advent Group, Inc. report of 1992.

Headwater and tributary dissolved oxygen were calculated at 80% of saturation, the highest percent saturation observed during the survey.

The monthly critical temperatures for Bayou Bartholomew were used for Chauvin Bayou.

4.3.2 The “Wet and Dry Bulb Temperatures for Shreveport and Jackson” sheet presents the data used to estimate wet bulb temperatures for Monroe. Only dry bulb temperatures were available for Monroe.

4.3.3 The “Average Monthly Wind Speed” sheet summarizes the wind speed data from the Office of State Climatology that was used for the projections.

4.3.4 The “Projection Point Source Input” sheets give the flows, temperatures, DOs, and other water quality data for point sources and tributaries. As indicated, the point source flows include a 20 percent margin of safety. The tributary loads include a 10 percent margin of safety. Load and flow reduction is indicated where it was applied.

4.3.5 The “Wind Aided Reaeration Calculations” are run for each month based on the critical flows and average wind speed for that month. The resulting reaeration rate is used in place of the reaeration equations available in Qual2E.

4.4 Steady State Projection Plots, Appendix H

Projection plots are provided for each month, and for projection runs without load reduction and with load reduction to meet criteria. The May, June, July, August, and September runs represent the summer season of May through October. The November run represents the winter season. The location of dischargers and some of the tributaries is marked on the water quality plots. The site locations are marked on the hydrologic plots. The DO criterion is marked on the dissolved oxygen plots. The critical temperature is marked on the temperature plots. The three estimates of Ouachita River 7Q10 are marked on the flow plots. The state line 7Q10 is used as the basis for the flow projection.

4.5 Projection Input and TMDL Worksheets, Appendix I

Worksheets are provided for each month, and for projection runs without load reduction and with load reduction to meet criteria. No reduction was required to meet criteria in May, June, or July. Identical load reductions were required to meet criteria in August and September. For those months, incremental input of CBOD, organic nitrogen, and organic phosphorus was reduced by 30%, headwater loading was reduced by 15%, and the flow from one point source, Riverwood International, was reduced by 15%. The August TMDL, being the smallest of the summer season monthly TMDLs, is considered to be the summer season TMDL.

As shown in Table 5, Riverwood is permitted to discharge BOD as a function of the Ouachita River flow as measured by the state line slope gauge. The flow at Riverwood Outfall 001 is regulated to stay within permit limitations for pounds per day of CBOD. The reduction of the Riverwood discharge is calculated as a reduction of the mass discharge but is modeled as a reduction in flow by assuming the CBOD concentration to be that measured during the survey.

No reduction was required to meet criteria in November. The most stringent flow and temperature conditions of the winter season occur in November, and the November run was therefore used to calculate the winter season TMDL. The winter TMDL does not represent the total assimilative capacity of this portion of the Ouachita River. Excess winter capacity over that allocated to point and nonpoint sources and margin of safety, does exist as evidenced by the difference between the projected and criteria dissolved oxygen. The amount of this excess varies with river mile and is held in reserve.

4.6 Input and Output Listings, Appendices J, K, and L

Projection output listings for the August run to meet criteria and the November run without load reduction are provided in Appendices K and L. Input listings are provided in Appendix J for the May, June, July, and September runs.

5. TMDL and Allocation Summary

Projections have been made for the months of May through September and November. The most critical conditions were encountered in August for the summer months and November for the winter months. The projections for these two months were used to calculate the summer and winter season

TMDLs. The projections indicate that the river is dominated by nonpoint but that point source impacts are significant. The minimum dissolved oxygen occurs in a portion of the river just upstream of the dam at Riverton, where the river velocities are lowest. In order to meet the August DO criteria of 4.5 mg/l it was necessary to reduce headwater loading by 15 percent, and nonpoint loading by 30 percent. It was also necessary to reduce the loading from Riverwood Outfall 001, Judy Slough, by 15 percent. No reductions were required for the winter season. The summer and winter allocations and TMDLs are as follows:

Table 7 - Summer Allocations and TMDLs

PARAMETER	WLA (lbs/day)	LA (lbs/day)	MOS (lbs/day)	TMDL (lbs/day)
UCBOD	21,406	101,947	16,679	140,032
ORG-N	7,334	21,990	4,277	33,601
NH_3-N	3,125	666	855	4,646
SOD	0	5.0	0.6	5.6
TOTAL	31,865	124,608	21,812	178,285

The summer season allocation for Riverwood International is lb CBOD5/day = 5.06Q-204, where Q is the seven day running average flow in cfs from the USGS state line slope gauge.

Table 8 - Winter Allocations and TMDLs

PARAMETER	WLA (lbs/day)	LA (lbs/day)	MOS (lbs/day)	TMDL (lbs/day)
UCBOD	28,841	139,057	22,661	190,558
ORG-N	8,505	27,779	5,213	41,497
NH_3-N	3,714	765	1,014	5,493
SOD	0	5.0	0.6	5.6
TOTAL	41,060	167,606	28,888	237,554

The winter TMDL does not represent the total assimilative capacity of this portion of the Ouachita River. Excess winter capacity over that allocated to point and nonpoint sources and margin of safety, does exist as evidenced by the difference between the projected and criteria dissolved oxygen. The amount of this excess varies with river mile and is held in reserve.

6. Sensitivity Analysis

All modeling studies necessarily involve uncertainty and some degree of approximation. It is therefore of value to consider the sensitivity of the model output to changes in model coefficients, and in the hypothesized relationships among the parameters of the model. The Qual2E model allows several parameters to be varied with a single run. The model adjusts each parameter up or down by the percentage given in the input set. The rest of the parameters listed in the sensitivity section are held at their original projection value. Thus the sensitivity of each parameter is reviewed separately. A sensitivity analysis was performed on the model calibration. The sensitivity of the model's minimum DO projections to these parameters is presented in Table 9. Qual2E does not generate plot files for sensitivity. The numbers in Table 9 were read from the sensitivity run output. Parameters were varied by +/- 30%, except temperature, which was adjusted +/- 2 degrees Centigrade.

As shown by the data, DO is most sensitive to stream reaeration, CBOD decay rate, temperature, headwater flow, and incremental flow.

Table 9 - Calibration Model Sensitivity

Parameter	Base DO (mg/l)	Percent variation	Delta DO (mg/l)	Percent change	Percent Variation	Delta DO (mg/l)	Percent change
Reaeration rate	4.52	+30	+0.47	+10.4	-30	-0.68	-15.0
CBOD decay rate	4.52	+30	-0.34	-7.5	-30	+0.42	+9.3
Temperature	4.52	+3.6 ^{o}F	-0.28	-6.2	-3.6^{o}F	+0.26	+5.8
Headwater flow	4.52	+30	+0.19	+4.2	-30	-0.25	-5.5
Incremental flow	4.52	+30	-0.17	-3.8	-30	+0.19	+4.2
Org-N decay rate	4.52	+30	-0.07	-1.5	-30	+0.08	+1.8
Algae respiration rate	4.52	+30	-0.04	-0.9	-30	+0.06	+1.3
Algae growth rate	4.52	+30	+0.03	+0.7	-30	-0.02	-0.4
Org-P decay rate	4.52	+30	0.0	0.0	-30	0.0	0.0

7. Nutrient Impacts

As evidenced by the increase in the level of chlorophyll-a in the projections, nutrients are predicted by the model to have some impact on water quality. Additional model runs were conducted to evaluate the impact of nutrients on Ouachita River dissolved oxygen at August critical conditions.

7.1 Sensitivity runs

Sensitivity runs were made on the "August projection to meet criteria". Nitrates, organic phosphorus, and soluble phosphorus were varied in the headwater and in point sources (including tributaries) and the impact on dissolved oxygen, chlorophyll a, total nitrogen, and total phosphorus noted. The results are summarized in Table 9. Plots showing the impact on these parameters may be found in Appendix M. Changes in nutrient loading are projected to have a substantial impact on algae levels in the river, but the projected impact on dissolved oxygen levels is not significant.

Table 10 - Projection Model Sensitivity to Nutrients

PERTURBATION	REACH & ELEMENT		PARA-METER	BASE (mg/l or ug/l)	CHANGE	% CHANGE
	FROM	TO				
Point source NO_3 & Org-P & Sol-P @ +100%	11-13	12-6	DO	4.8	+0.12	+2.5
	9-4	9-18	TN	1.41	+0.32	+22.7
	9-4	9-12	TP	0.23	+0.15	+65.2
	17-12	17-12	Chl-a	39.3	+37.9	+96.4
Point source NO_3 & Org-P & Sol-P @ -50%	17-12	17-12	DO	5.72	-0.11	-1.9
	9-4	11-2	TN	1.41	-0.16	-11.3
	9-4	16-8	TP	0.23	-0.07	-30.4
	17-12	17-12	Chl-a	39.3	-17.9	-45.5
Headwater NO_3 & Org-P & Sol-P @ +100%	2-4	2-11	DO	6.01	+0.06	+1.0
	1-1	2-5	TN	0.80	+0.14	+17.5
	1-1	2-7	TP	0.06	+0.06	+100.0
	17-12	17-12	Chl-a	39.3	+15.1	+38.4
Headwater NO_3 & Org-P & Sol-P @ -50%	1-20	2-11	DO	6.01	-0.03	-0.5
	1-1	2-7	TN	0.80	-0.07	-8.8
	1-1	2-11	TP	0.06	-0.03	-50.0
	17-12	17-12	Chl-a	39.3	-8.1	-20.6

7.2 Calibration and Projection Without Nutrient-Algae cycle

The model was recalibrated without running the nutrient-algae cycle, and that calibration used as a basis for a rerun of the "August projection without load reduction". The intent was to evaluate the impact of the nutrient-algae cycle on projection results. Note that the global constants that control solar radiation, evaporation, and algae growth and respiration do not function in this mode. The calibration plots for water quality parameters may be found in Appendix M. The hydrologic calibration was unchanged, so only the water quality calibration was plotted. Since neither chlorophyll a nor temperature were modeled, the calibration for these parameters reflects the survey data input as initial conditions. Chlorophyll a levels are not impacting the calibration projection but the rates and DO saturation are, of course, a function of temperature.

The projection charts show the difference between a full nutrient-algae cycle model and a model of the oxygen demanding load only. The nutrient cycle projected dissolved oxygen includes the net of algae production and respiration, and that is, of course, the difference between the DO plots. The net algae production at the point of minimum dissolved oxygen is a positive 0.1 mg/l. The plots for organic nitrogen, ammonia, nitrite plus nitrate nitrogen, and total nitrogen are also shown.

Neither these model runs nor the sensitivity runs indicate that the dissolved oxygen is significantly impacted by increased nutrient discharges or by increased nutrient levels in the Ouachita River. This work does not, therefore, suggest that a TMDL for nutrients is needed.

8. Conclusions

The Ouachita River behind the Columbia Dam is a long, deep, slow flowing pool at critical flow. This adversely affects the dissolved oxygen levels in the river. The water quality is dominated by nonpoint loading but point sources are also very significant. Point source and nonpoint source reductions are required in order that the dissolved oxygen criteria may be met in the summer season months of May through October. No reductions are required in the winter season.

Additional model runs were conducted to evaluate the impact of nutrients on Ouachita River dissolved oxygen at August critical conditions. These model runs did not indicate that the dissolved oxygen is significantly impacted by increased nutrient discharges or by increased nutrient levels in the Ouachita River. This work does not, therefore, suggest that a TMDL for nutrients is needed.

This TMDL was developed in accordance with the Louisiana anti-degradation policy, Title 33:IX.1109. LDEQ will work with other agencies such as local Soil Conservation Districts to implement agricultural best management practices in the watershed through the 319 programs. Louisiana's Nonpoint Source Pollution Management Plan outlines Louisiana's approach to nonpoint source pollution control. It describes the types of projects that have been and will be implemented, and it presents information on BMPs that have been determined to be technically feasible and effective in reduction of pollutant loadings and runoff. LDEQ will also continue to monitor the waters to determine whether standards are being attained.

In accordance with Section 106 of the federal Clean Water Act and under the authority of the Louisiana Environmental Quality Act, the LDEQ has established a comprehensive program for monitoring the quality of the state's surface waters. The LDEQ Surveillance Section collects surface water samples at various locations, utilizing appropriate sampling methods and procedures for ensuring the quality of the data collected. The objectives of the surface water monitoring program are to determine the quality of the state's surface waters, to develop a long-term database for water quality trend analysis, and to monitor the effectiveness of pollution controls. The data obtained through the surface water monitoring program is used to develop the state's biennial 305(b) report (*Water Quality Inventory*) and the 303(d) list of impaired waters. This information is also utilized in establishing priorities for the LDEQ nonpoint source program.

The LDEQ has implemented a watershed approach to surface water quality monitoring. Through this approach, the entire state is sampled over a five-year cycle with two targeted basins sampled each year. Long-term trend monitoring sites at various locations on the larger rivers and Lake Pontchartrain are sampled throughout the five-year cycle. Sampling is conducted on a monthly basis or more frequently if necessary to yield at least 12 samples per site each year. Sampling sites are located where they are considered to be representative of the waterbody. Under the current monitoring schedule, targeted basins follow the TMDL priorities. In this manner, the first TMDLs will have been implemented by the time the first priority basins will be monitored again in the second five-year cycle. This will allow the LDEQ to determine whether there has been any improvement in water quality following implementation of the TMDLs. As the monitoring results are evaluated at the end of each year, waterbodies may be added to or removed from the 303(d) list.

In addition to surface water monitoring, municipal and industrial point source dischargers are monitored to verify compliance with permitted effluent limitations and compliance schedules. Major dischargers are inspected annually (with sampling when necessary) to ensure compliance with applicable effluent limitations and state and federal permit requirements.

9. References

Bowie, G. L., et. al. *Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling* (Second Edition). Env. Res. Lab., USEPA, EPA/600/3-85/040. Athens, GA: 1985.

Louisiana Department of Environmental Quality. *State of Louisiana Water Quality Management Plan, Volume 6, Part A, Nonpoint Source Pollution Assessment Report.* Baton Rouge, LA: 1993.

Louisiana Department of Environmental Quality. *State of Louisiana Water Quality Management Plan, Volume 5A, Water Quality Data Summary, 1992-1993.* Baton Rouge, LA: 1994 *State of Louisiana Water Quality Management Plan, Volume 6, Part A, Nonpoint Source Pollution Assessment Report.*.

Louisiana Department of Environmental Quality. Environmental Regulatory Code, Part IX. Water Quality Regulations. Baton Rouge, LA: 2000.

Waldon, M. G., R. K. Duerr, and Marian U. Aguillard. *Louisiana Total Maximum Daily Load Technical Procedures*. Louisiana Department of Environmental Quality. Baton Rouge, LA: May, 2001.

Lee, F.N. *Low Flow on Streams in Louisiana.* Prepared for Louisiana Department of Environmental Quality. Baton Rouge, LA: March, 2000.

U.S. Environmental Protection Agency. *The Enhanced Stream Water Quality Models, Qual2E and Qual2E-UNCAS*. May, 1987.

U.S. Environmental Protection Agency. *Qual2E Windows User's Guide*. August, 1995.

AquAeTer, Inc., Brentwood, TN. *Total Maximum Daily Load Projections, Ouachita River, Felsenthal Lock and Dam, Arkansas to Sterlington, Louisiana*. Prepared for Arkansas Department of Environmental Quality, Little Rock, Arkansas. April, 1999.

HydroQual, Inc., Mahwah, NJ. *Development of a Water Quality Model of the Ouachita River*. Prepared for Georgia-Pacific Corp., Crossett, Arkansas. July, 1992.

Thomann, Robert V. and Mueller, John A. *Principles of Surface Water Quality Modeling and Control.* Manhattan College, 1987.